3D PRINTED MEMBRANE-TYPE ACOUSTIC METAMATERIALS FOR SMALL-SCALE APPLICATIONS

Cecilia Casarini, Ben Tiller, James F.C. Windmill and Joseph C. Jackson

Centre for Ultrasonic Engineering
Department of Electronic & Electrical Engineering
University of Strathclyde, Glasgow UK

European Research Council
Established by the European Commission

OUTLINE

- ❑ Background and Motivations
- ❑ Acoustic metamaterials based on Helmholtz resonators
- ❑ 3D printing membranes
- ❑ Membranes-type metamaterials
- ❑ Conclusions and Future Work

BACKGROUND AND MOTIVATIONS

University of Strathclyde Engineering

3D PRINTED MEMBRANE-TYPE ACOUSTIC METAMATERIALS FOR SMALL-SCALE APPLICATIONS

BACKGROUND AND MOTIVATIONS

University of Strathclyde Engineering

3D PRINTED MEMBRANE-TYPE ACOUSTIC METAMATERIALS FOR SMALL-SCALE APPLICATIONS

- Lightweight, small scale
- There is a large range of materials to choose from with different properties
- It is possible to change the resonance frequency by modifying the design (DMM, etc.)

BACKGROUND AND MOTIVATIONS

University of Strathclyde Engineering

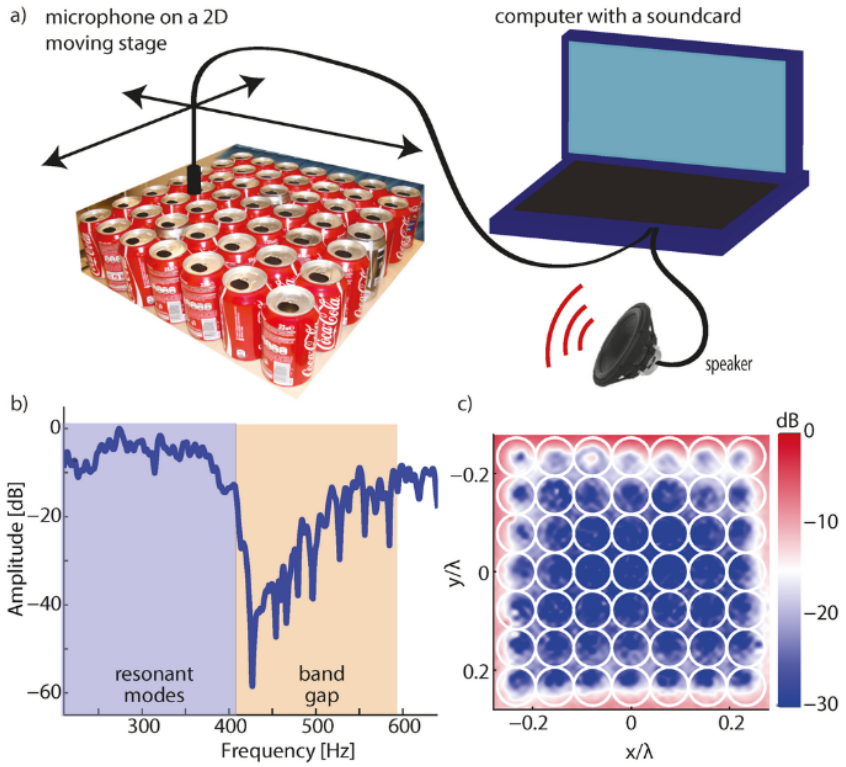
- The need for developing 3D printing techniques for membrane-type acoustic metamaterials has been highlighted in papers
- 3D printing gives a high degree of similarity among the samples, which is difficult to obtain in manually glued membranes

3D PRINTED MEMBRANE-TYPE ACOUSTIC METAMATERIALS FOR SMALL-SCALE APPLICATIONS

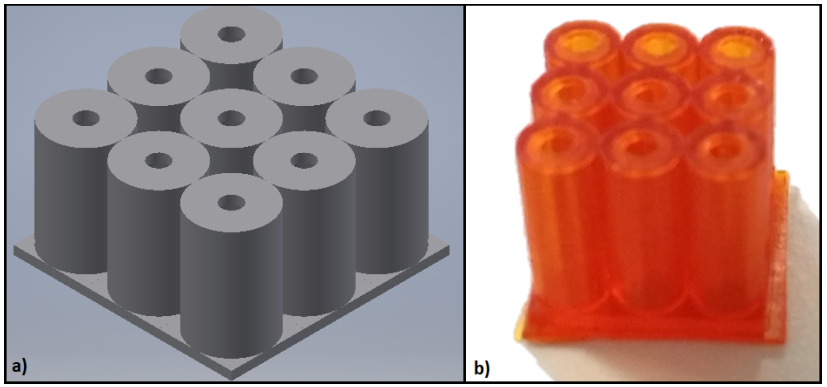
- Lightweight, small scale
- There is a large range of materials to choose from with different properties
- It is possible to change the resonance frequency by modifying the design (DMM, active membranes, etc.)

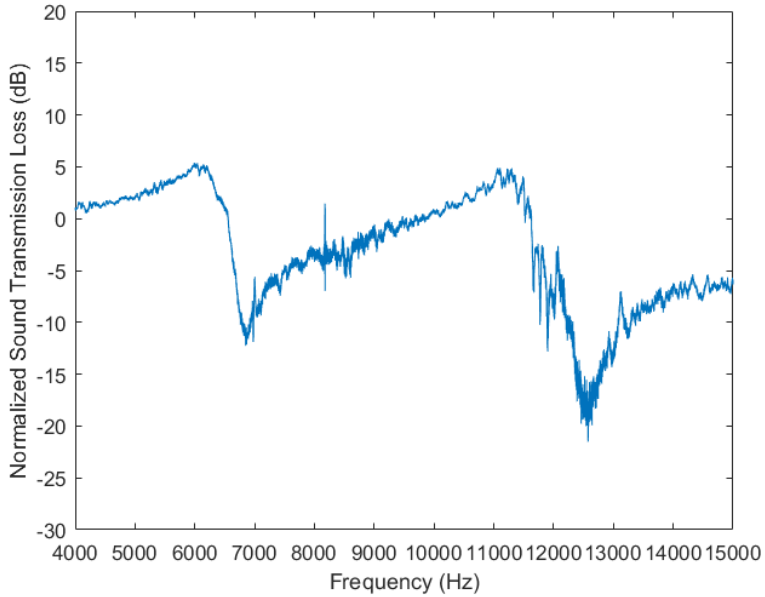
ACOUSTIC METAMATERIALS BASED ON HELMHOLTZ RESONATORS

University of Strathclyde Engineering



Lemoult, F., Kaina, N., Fink, M., and Lerosey, G. (2013). Wave propagation control at the deep subwavelength scale in metamaterials. Nat Phys, 9(1):55{60.



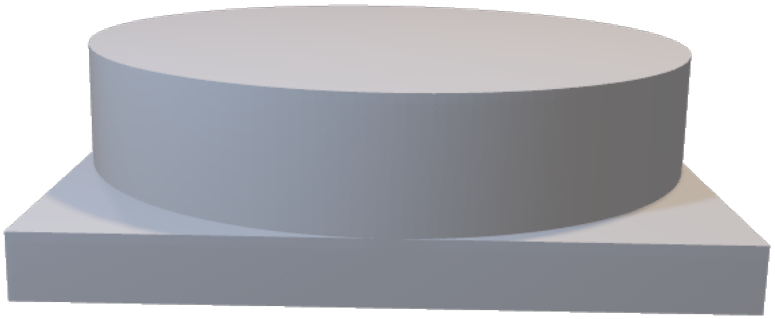


Casarini, C., Windmill, J.F.C., Jackson, J.C. (2017) 3D printed small-scale acoustic metamaterials based on Helmholtz resonators with tuned overtones. In IEEE Sensors Conference, 2017

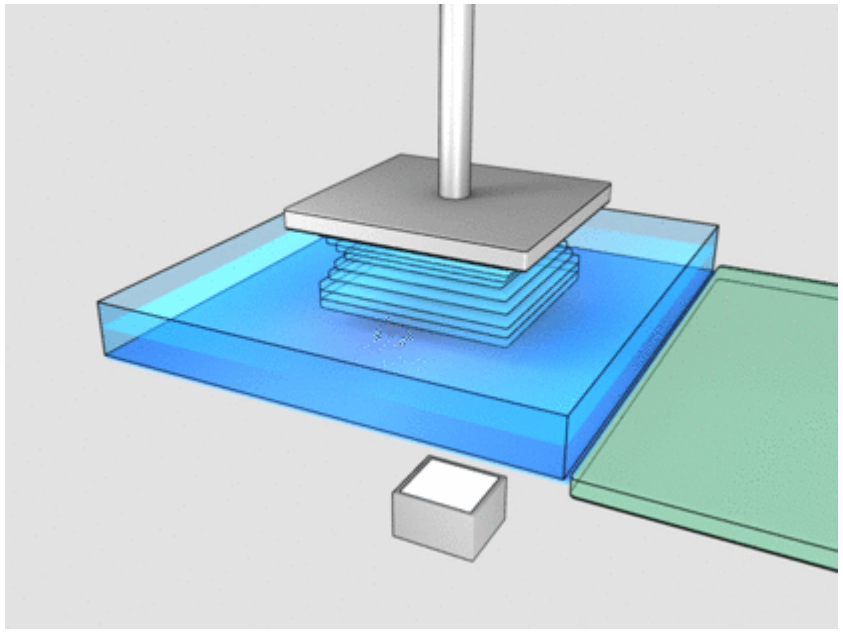
3D PRINTING MEMBRANES

University of Strathclyde Engineering

CAD Model



Upside-Down Stereolithography

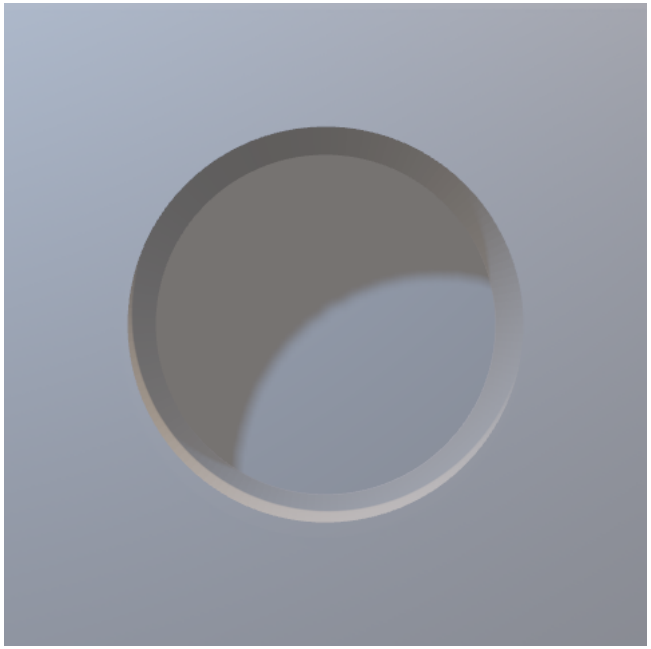


https://www.asiga.com

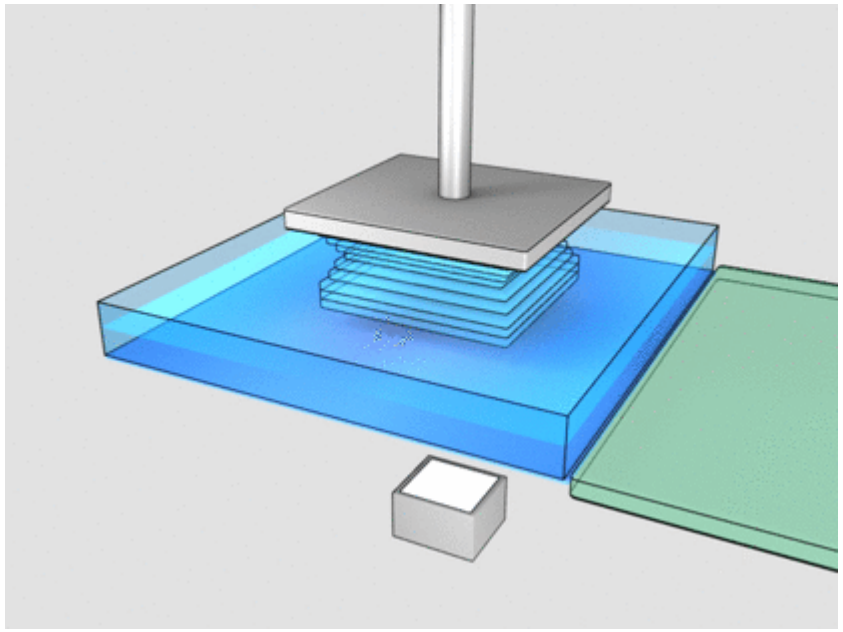
3D PRINTING MEMBRANES

University of Strathclyde Engineering

CAD Model



Upside-Down Stereolithography

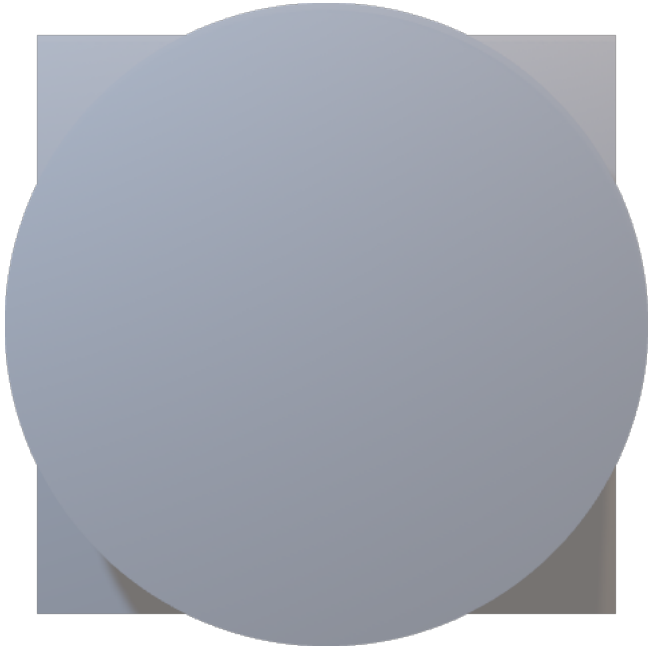


https://www.asiga.com

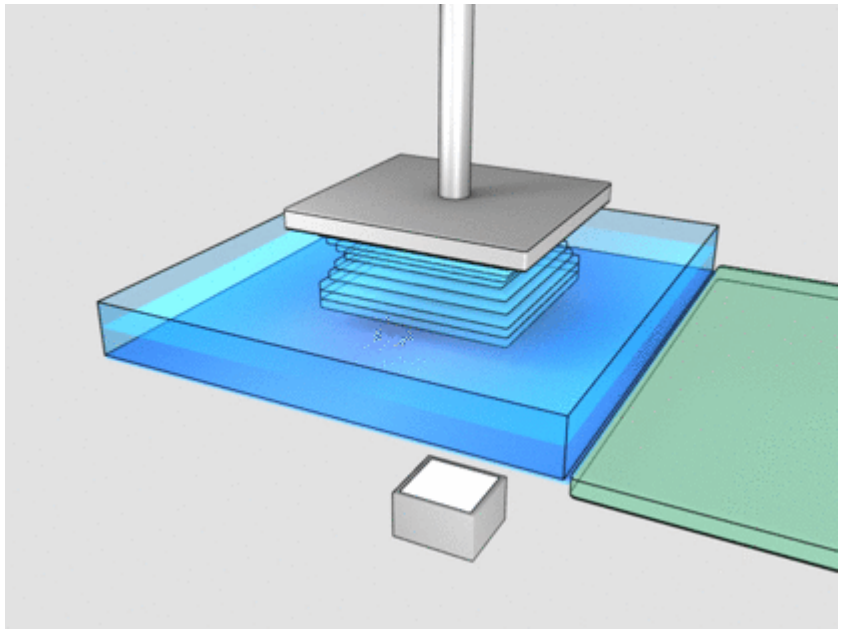
3D PRINTING MEMBRANES

University of Strathclyde Engineering

CAD Model



Upside-Down Stereolithography



https://www.asiga.com

3D PRINTING MEMBRANES

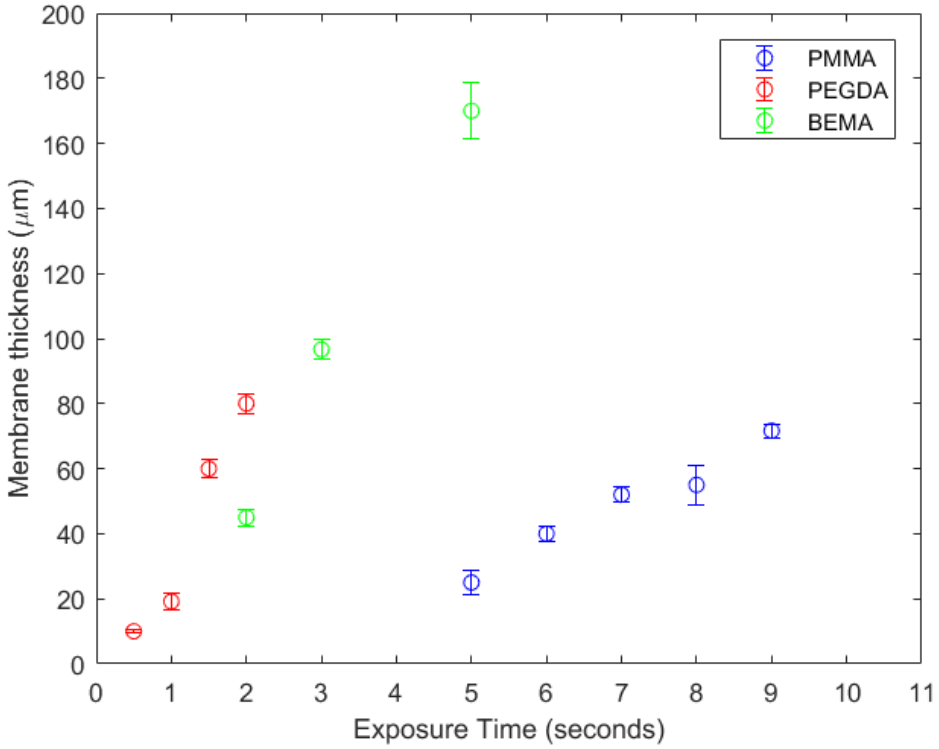
University of Strathclyde Engineering

Materials Properties

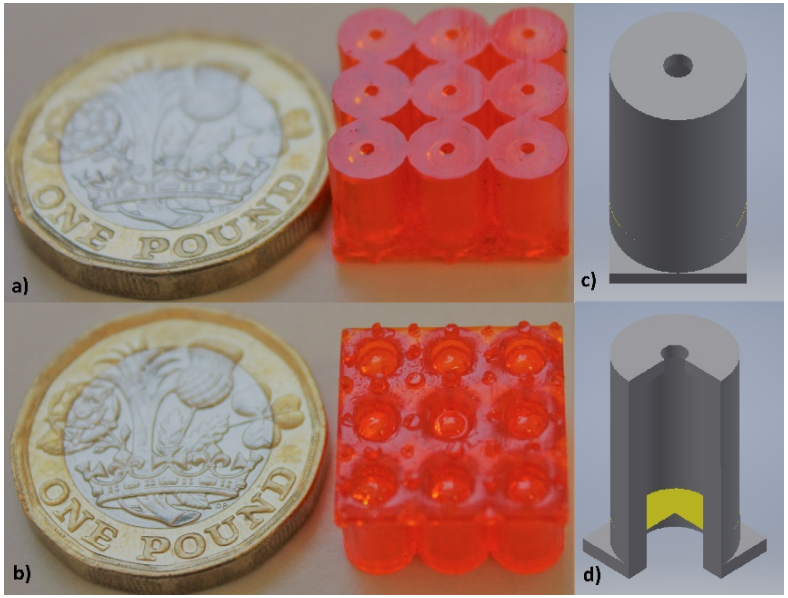
	PMMA	PEGDA	BEMA
Young's Modulus (*Pa*)	1.8 X 10^9	50 X 10^6	3 X 10^6
Density (Kg/m^3)	1180	1180	1099
Poisson's Ratio	0.33	0.35	0.4

- Trial and error process
- Increasing exposure time increases the thickness
- Increasing the quantity of absorber decreases the thickness
- Different materials need different exposure times and amount of absorber to obtain the same thickness

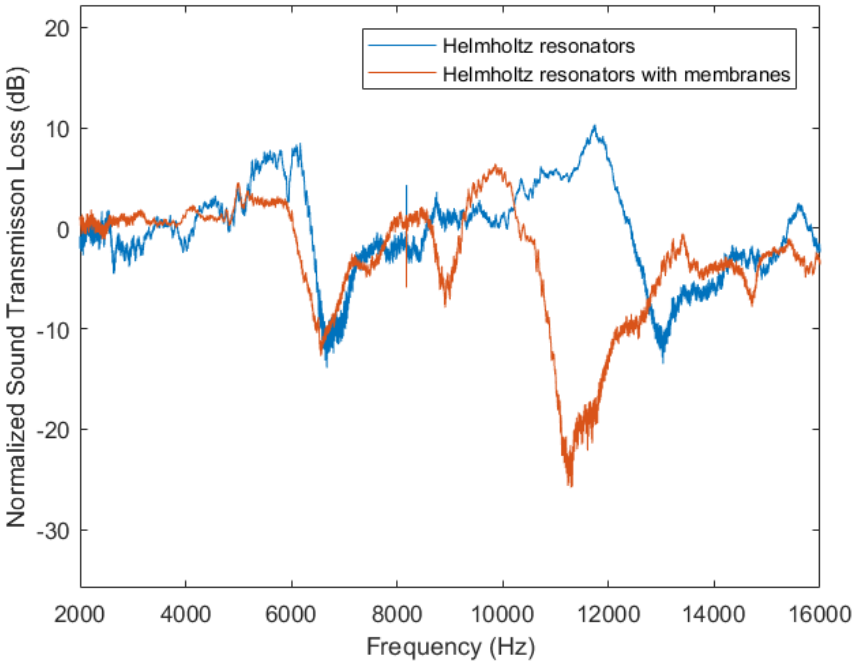
Thickness – Exposure Time



ACOUSTIC METAMATERIALS BASED ON 3D PRINTED MEMBRANES



- Membranes increase and broaden the bandgap
- The resonance frequency is higher than expected due to stress added by the 3D printer



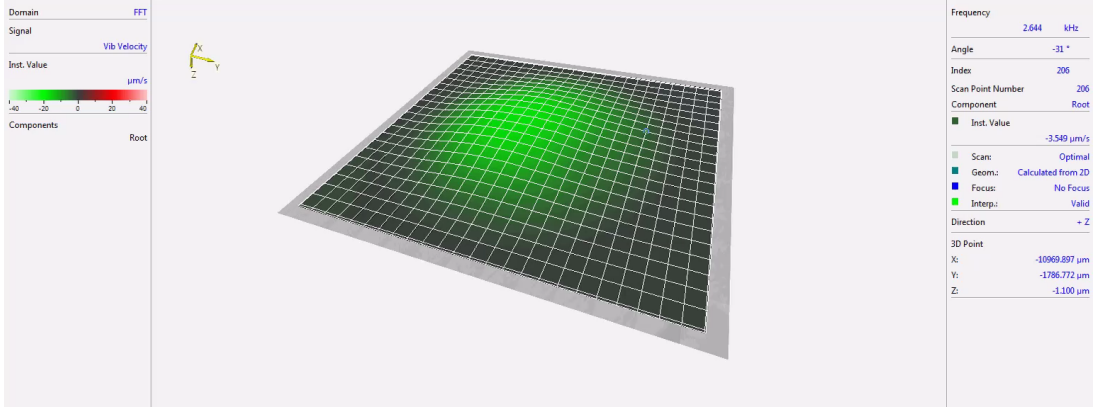
University of Strathclyde Engineering

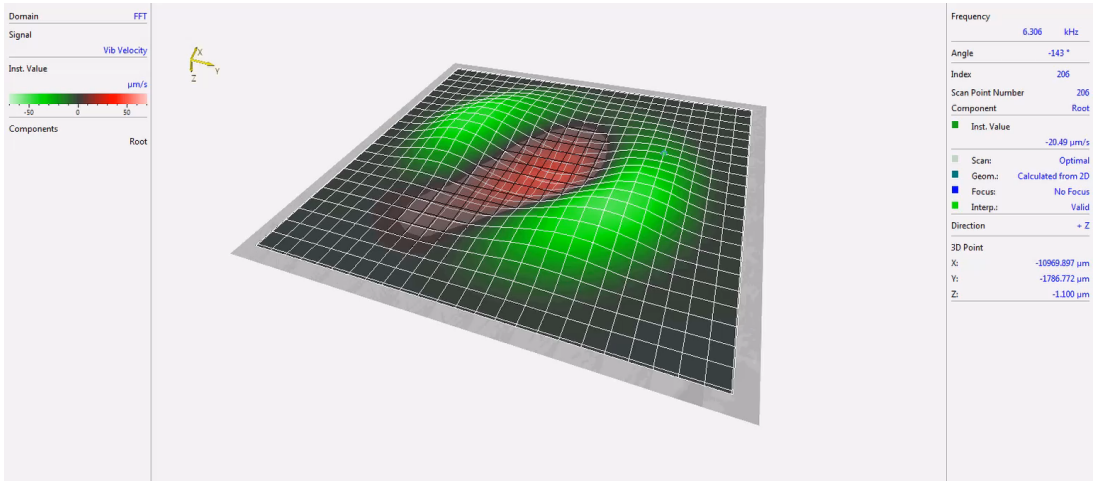
CONCLUSIONS

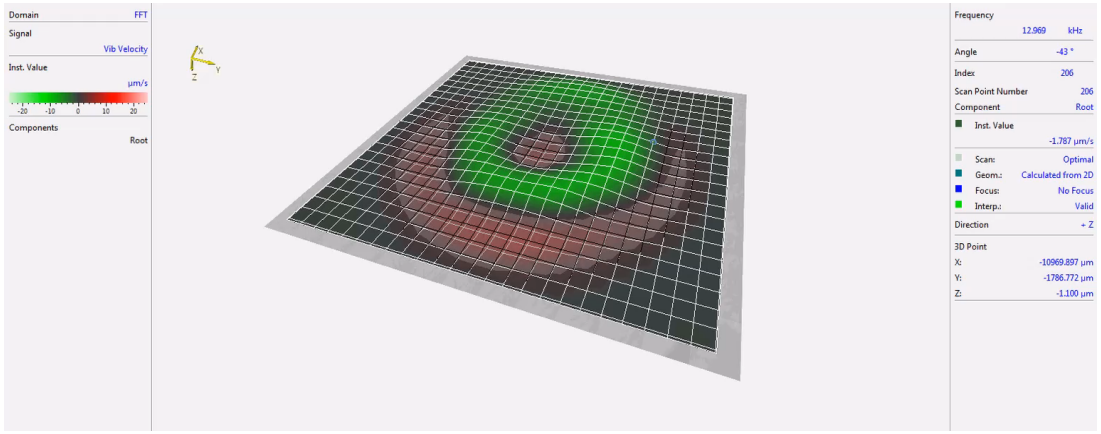
- We successfully 3D printed thin membranes.
- By printing the membranes on the bottom of Helmholtz resonators it was possible to achieve broader and deeper band gaps.
- However, the resonance frequency of the membranes was higher than the one predicted analytically.

FUTURE WORK

- To test the sound transmission loss through impedance tube or other measurement techniques.
- To design and print acoustic metamaterials based on different kind of membranes and materials.
- To finally build and test audio devices and conduct psychoacoustic evaluations.







University of Strathclyde Engineering

University of Strathclyde Engineering

CONCLUSIONS

- We successfully 3D printed thin membranes.
- By printing the membranes on the bottom of Helmholtz resonators it was possible to achieve broader and deeper band gaps.
- However, the resonance frequency of the membranes was higher than the one predicted analytically.

FUTURE WORK

- To test the sound transmission loss through impedance tube or other measurement techniques.
- To design and print acoustic metamaterials based on different kind of membranes and materials.
- To finally build and test audio devices and conduct psychoacoustic evaluations.

THANK YOU!

University of Strathclyde Engineering

CONCLUSIONS

- We successfully 3D printed thin membranes.
- By printing the membranes on the bottom of Helmholtz resonators it was possible to achieve broader and deeper band gaps.
- However, the resonance frequency of the membranes was higher than the one predicted analytically.

FUTURE WORK

- To test the sound transmission loss through impedance tube or other measurement techniques.
- To design and print acoustic metamaterials based on different kind of membranes and materials.
- To finally build and test audio devices and conduct psychoacoustic evaluations.